N87-16424

RAPID THERMAL PROCESSING OF CZOCHRALSKI SILICON SUBSTRATES: DEFECTS, DENUDED ZONES, AND MINORITY CARRIER LIFETIME

NORTH CAROLINA STATE UNIVERSITY

G. S. Rozgonyi, D. K. Yang, Y. H. Cao, and Z. Radzimski

Rapid Thermal Processing of Czochralski Silicon: Objectives

To evaluate rapid thermal processing as a viable procedure for:

1. **Czochralski substrate modification using high temperature defect-dissolution treatments,**
2. **Rapid junction activation following ion implantation**

Diagnostic Tools

1. **MOS Capacitor -- minority carrier lifetime**
2. **X-Ray Topography -- defect delineation**
3. **Nomarski Optical Microscopy & Preferential Chemical Etching -- defect delineation**
4. **Fourier Transform Infrared Microscopy -- oxygen precipitation kinetics**

Metal Oxide Semiconductor Capacitor – C

1. **Capacitance-voltage (C-V) measurements**
2. **Capacitance-time (C-t) measurements**
3. **C-V, C-t measurements at different temperatures T**
4. **Minority carrier generation and recombination lifetime (τ_g and τ_r)**

Change of Inversion Layer Charge Density with Time

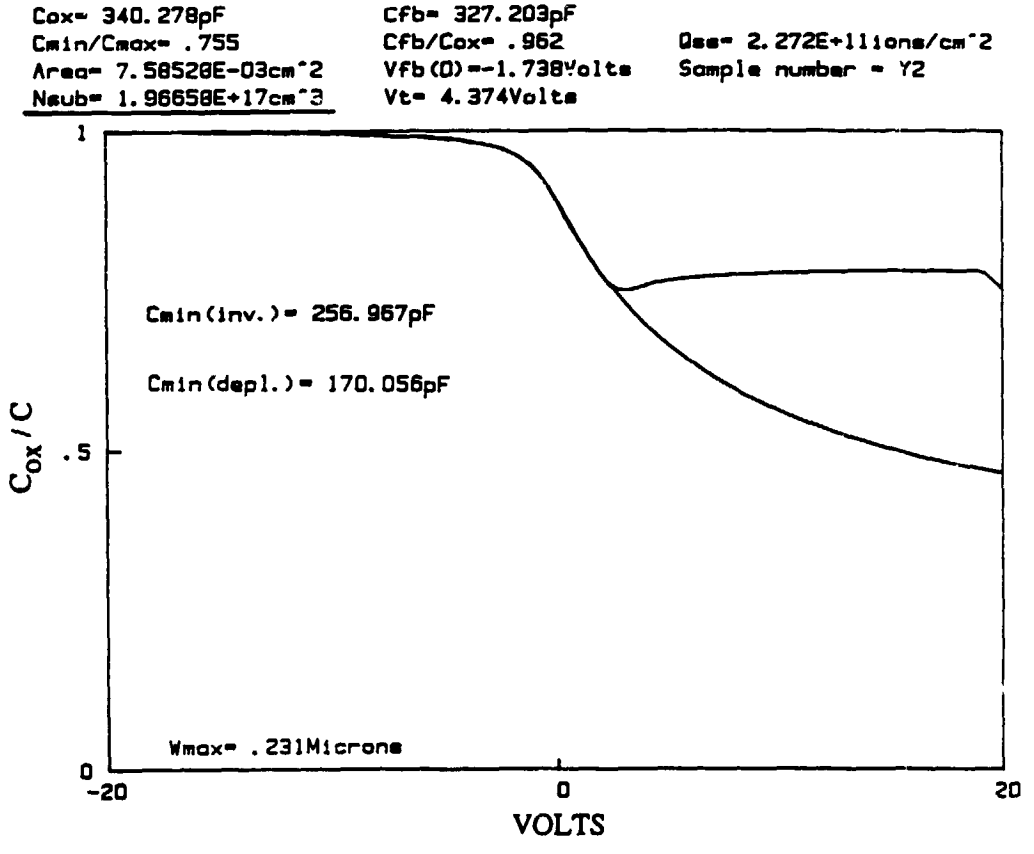
$$\frac{dn_s}{dt} = \underbrace{\left(\frac{n_i (W - W_F)}{\tau_g} + n_i s\right)}_{} + \underbrace{\left(\frac{n_i^2 D_n}{N_A L_n}\right)}_{B}$$

Room temperature $A \gg B$ **(Zerbst, 1966)**

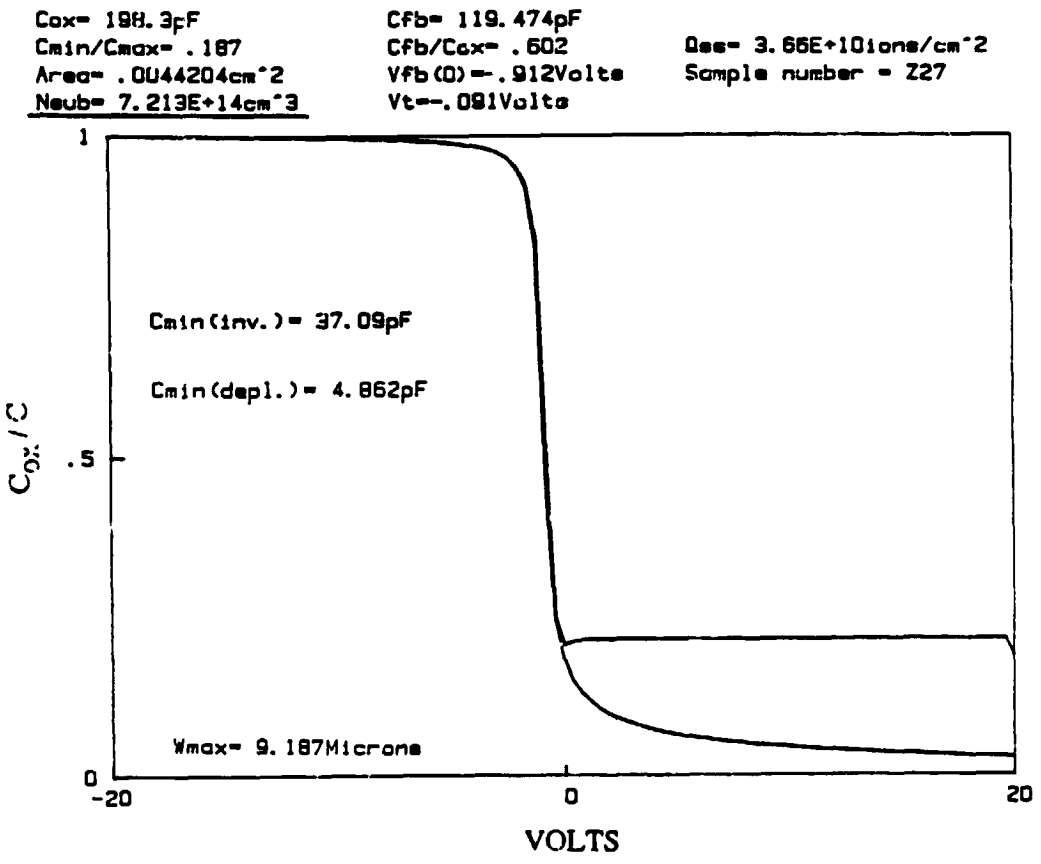
Elevated temperature $A \ll B$ **(Schroder, 1984)**

- n_s - **inversion layer charge density**
- W_F - **final space charge region width**
- W - **space charge width**
- n_i - **intrinsic carrier density**
- D_n - **diffusion constant**
- L_n - **diffusion length**
- N_A - **substrate doping concentration**
- τ_g - **generation lifetime**
- s - **surface recombination velocity**
- τ_r - **recombination lifetime** ($\tau_r = L_n^2/D_n$)

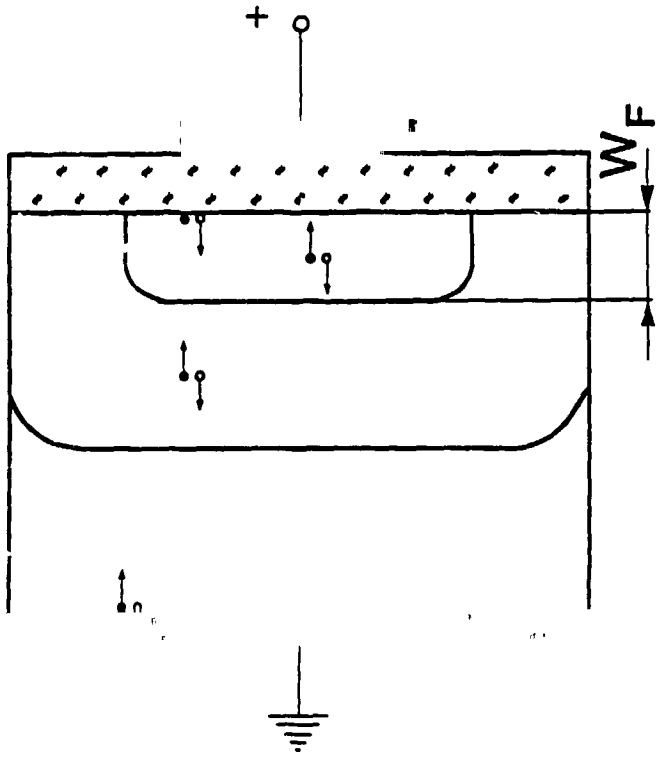
Capacitance Versus Voltage (Sample Y2)



Capacitance Versus Voltage (Sample Z27)



Zerbst Analysis (Room Temperature)

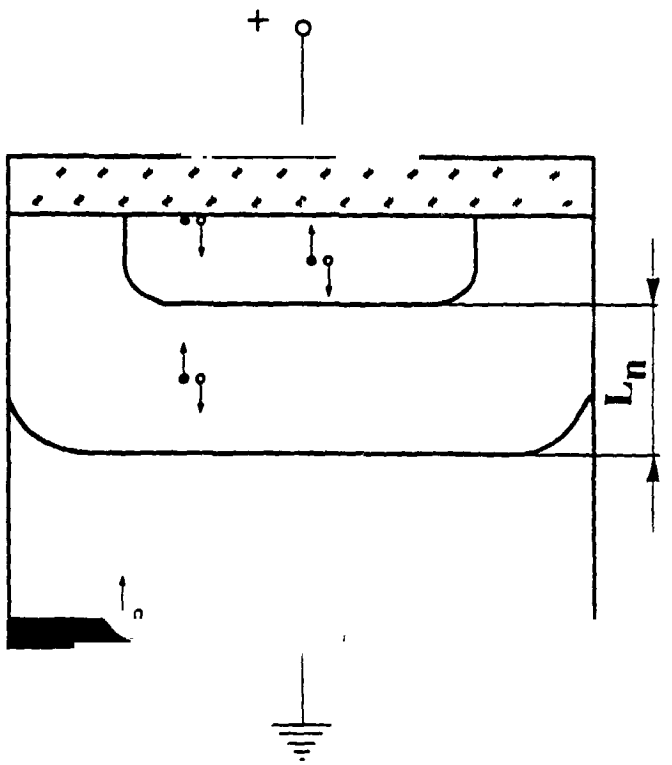


$$\frac{-d\,(C_{ox}/C)}{dt} \quad \text{vs} \quad \frac{C_F}{C-1}$$

τ_g œ slope

s œ intercept

Schroder Analysis (Elevated Temperature)

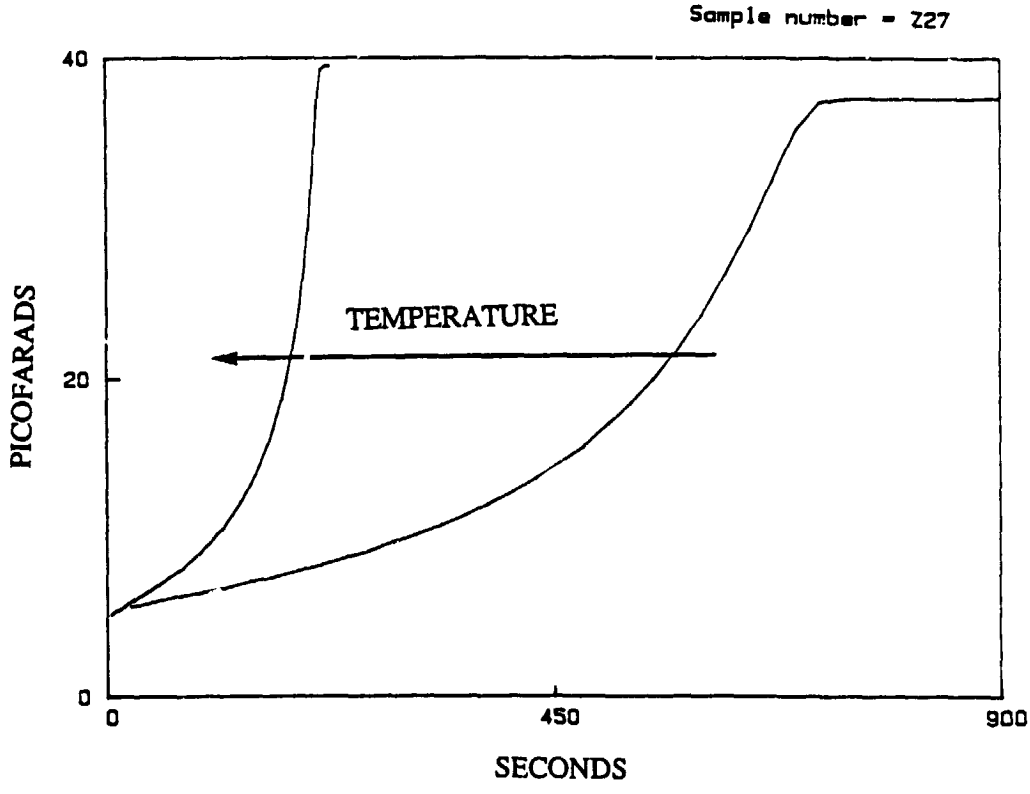


$\tau_r \propto L_n^2$

$1 - (C_F / C)^2$ vs time

$L_n \propto$ slope

Capacitance Versus Time (Sample Z27)



X-Ray Topography

1. **X - Ray Source: Marconi-Elliot GX-21 (15kW, Rotating anode)**

2. **Cameras: - Lang Transmission**
   - Double Crystal

3. **Sample treatment conditions:**
   - i. **Virgin**
   - ii. **Lo-Hi + RTP combination**
   - iii. **Li decoration**

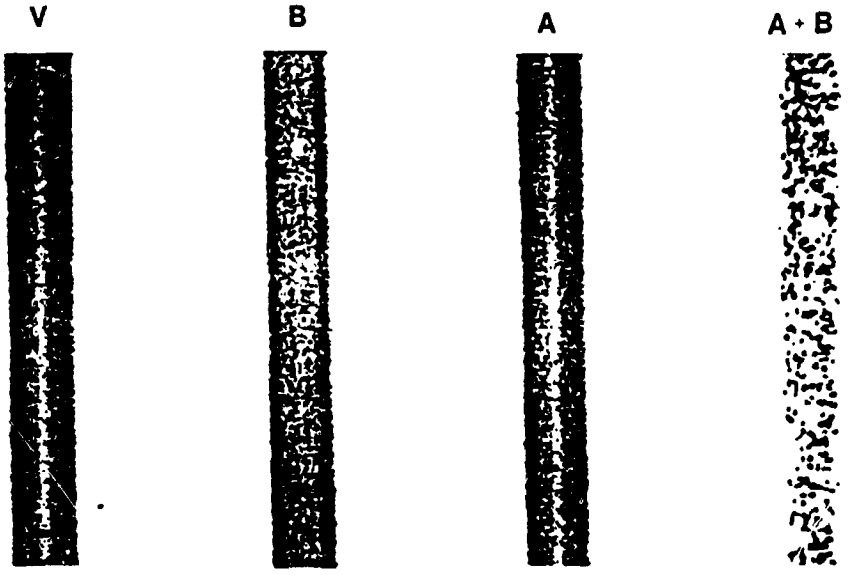
Surface Recombination Velocity/X-Ray Topography

MoK_α 220 X30

V: Virgin

A: 700°C / 16h dry O_2 + 0.0425HCL

B: 1100°C / 10min dry O_2 + 60minwet O_2 + 10min dry O_2



Nomarski Optical Microscopy and Preferential Chemical Etching

Etchant: Secco

Observation:
1. Depth of denuded zone (DZ)
2. Density and size of oxygen precipitates, stacking faults and dislocation.

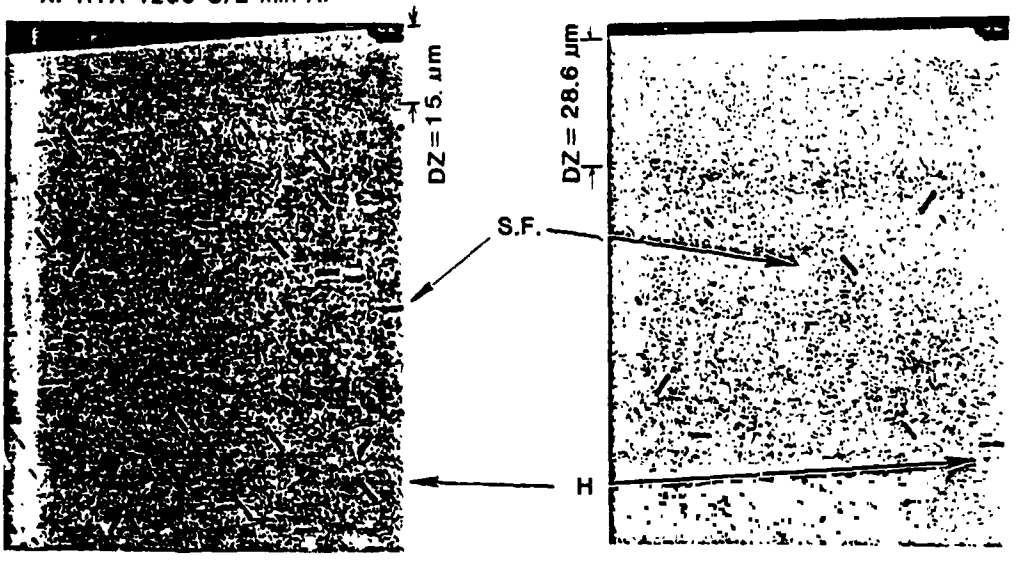
PROCESSING

ORIGINAL PAGE IS
OF POOR QUALITY

P: 700°C/16h dry O_2+2% HCl+1100°C/(10min dry+65min wet+10min)O_2+2% HCl +1100°C/15min dry O_2+2% HCl

V: Virgin

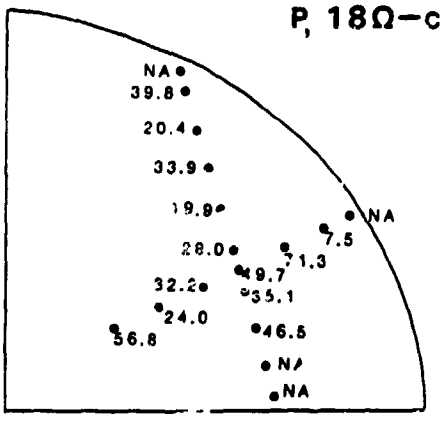
X: RTA 1200°C/2 min Ar



V + P

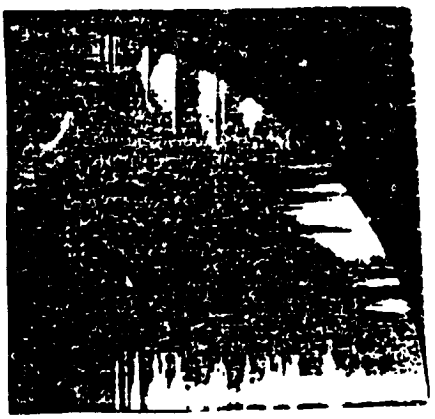
X + P

Minority Carrier Lifetime (Units in μs)



Heat Treatment

RTP(1200°C/2min) in Ar
+1100°C/(10min dry+65min wet+10min dry)O_2



Heat Treatment of Samples

A : 700°C/16h dry O_2 + 2% HCl

B : 1100°C/(10 min dry+65 min wet+10 min dry)O_2 + 2% HCl

C : 1100°C/15 min dry O_2

V : Virgin
X : RTP 1200°C/2 min in Ar
Y : 1200°C/30 min in Ar
Z : 1250°C/30 min in dry O_2 + 2% HCl
w : 1250°C/30 min in Ar

Arrays of Heat Treatments

	C	A+C	B+C	A+B+C
V	V+C	V+A+C	V+B+C	V+A+B+C
X	X+C	X+A+C	X+B+C	X+A+B+C
Y	Y+C	Y+A+C	Y+B+C	Y+A+B+C
Z	Z+C	Z+A+C	Z+B+C	Z+A+B+C
W	W+C	W+A+C	W+B+C	W+A+B+C

Heat Treatment of Samples

A : 700°C/16h dry O_2 + 2% HCl

B : 1100°C/(10 min dry+65 min wet+10 min dry)O_2 + 2% HCl

C : 1100°C/15 min dry O_2 + 2% HCl

V : Virgin
X : RTP 1200°C/2 min in Ar
Y : 1200°C/30 min in Ar
Z : 1250°C/30 min in dry O_2 + 2% HCl
W: 1250°C/30 min in Ar

C
A + C
B + C
A + B + C

Minority Carrier Lifetime (τ_g, μs)

	V+C	X+C	X+A+B+C
Group Z1	111.0	15.6	83.8
Group Z2	57.5	85.7	159.0
	V+C	Z+C	Z+A+B+C